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THE DEVELOPMENT OF PRODUCTION MANAGEMENT CONCEPTS

Anna KOSIERADZKA*, Urszula KĄKOL, Anna KRUPA*****

Faculty of Management,
Warsaw University of Technology, Warsaw, Poland
e-mail: *a.kosieradzka@wz.pw.edu.pl; **u.kakol@wz.pw.edu.pl; ***anna_krupa@wp.pl

Abstract: The aim of this paper is the analysis of contemporary concepts used in production management in relation to the paradigms which accompanied their appearance and development. The first chapter contains a definition of the term 'paradigm', discusses the importance of the paradigms for the development of a scientific approach to management and lists examples of paradigms relevant to production management. In the second chapter such management concepts as LM, Kaizen, TOC, TQM, TPM, Six Sigma and BPR are presented, along with their respective old and new paradigms, main goals, fundamental rules and tools (methods and techniques). Some less popular concepts are also dealt with. The last chapter is devoted to an analysis of interactions between the analyzed concepts, with an emphasis on their mutual compatibility and complementarity, which can be of benefit in the process of their implementation.

Key Words: Lean Management, Theory of Constraints, Kaizen, Total Quality Management, Six Sigma, Business Process Re-engineering, Agile Manufacturing, Mass Customization, management paradigms, production knowledge, management by projects.

1 Introduction

Each field of science develops through both revolutionary and evolutionary processes. Groundbreaking discoveries alternate with periods of gradual improvement and consolidation of methods, techniques, research and implementation tools. This is also the case in the field of management. From time to time concepts emerge which break with the old paradigms or modify them substantially.

S. Nowosielski describes management concepts as "(…) recipes for, or ideas of, management, which are the result of interpretation and generalization of practical experience, coming from a certain area of an organization's activity. They encompass a "soft" aspect, related to the general idea (philosophy) and a "hard" aspect, describing specific tools for realizing the company's vision" ([36], p. 10).

The aim of this paper is to describe the key concepts used nowadays in production management:

- LM – Lean Manufacturing,
- TOC – Theory of Constraints,
- TQM – Total Quality Management,
- Six Sigma,
- TPM – Total Productive Maintenance,
- Kaizen – continuous improvement,
- BPR – Business Process Reengineering.

Other concepts dealt with here include: agile manufacturing, mass customization, management through projects and production knowledge management. These concepts are still being developed in terms of the techniques and methods they employ.

Some authors point out that the increasing commercialization of management has created the necessity for a critical perspective on the methods and concepts popular these days: "management concepts marketed by business consultants and gurus have a lot of weaknesses. Accepting them uncritically is, therefore, not recommended." ([53], p. 170).

The concepts selected for analysis in this paper have proved to be successful in many countries, have been described well in the literature and are generally recognized and applied in everyday management practices. Emphasis has been placed on the use of these concepts in production management, highlighting at the same time their universal applicability and potential for use in organization management in general, not only for manufacturing.

New management concepts appear when in a given economy new problems arise. In order to find the solution for them one has to be capable of looking at the issue at hand from a different perspective, going beyond the entrenched conventions, which results in stepping outside the current paradigm and creating a new one.

This paper defines the concept of a paradigm and presents examples of paradigms relevant in production management. Fundamental models applied in production management are described. The breakthrough which accompanied their development is illustrated by contrasting the new and the old paradigm. Each model is characterized in terms of its fundamentals and methods and techniques used.

Interrelationships between different models are shown, which result from shared methods among other things. In the conclusion, the case for simultaneous implementation of contemporary production management models is made, as the compatibility of the models creates potential for synergy.

2 Production management paradigms

The word 'paradigm' comes from Greek and means "pattern, example" ([28], p. 457). It is a "a thought, pattern, model, or approach generally accepted in a given field" ([28], p. 457). The notion of paradigm in the historical development of science was introduced by TS. Kuhn, who defined it as "generally recognized scientific achievements which at a given time provide the scientific community with model problems and solutions" ([27], p. 12). Kowalczewski defines paradigm as "a model generally accepted by the scientific community of a given time and widely used" ([26], p. 24).

Many authors discuss the issue of paradigm changes in management science, particularly in relation to the novel view of organization as networked and virtual, the novel roles of directors (as leaders, coaches) ([35], p. 11), or the development of a knowledge and e-commerce based economy ([12], p. 13-14).

There are many management paradigms, which have been modified over the course of time. As a result of the world economy evolving towards globalization, it seems necessary to embrace the need for speed, agility and continuous changes. It is brought about not only by focusing on customer needs, but also by growing competition from fast developing Asian countries. Table 1 illustrates traditional paradigms and examples of new ones, with particular emphasis on production management.

The most important changes in production management paradigms will be discussed in the remainder of this paper.

Table 1. Examples of traditional and new production management paradigms
(source: self study on the basis of [18, p. 193])

Aspects	Traditional paradigms	New paradigms
Strategic management	5 years	1-2 years
Tactic management	2-3 years	6-18 months
Operational management	3 months	1 week
Freezed master schedule	3 months	1week
Freezed operational schedule	1 month	1 day
Machine inspection	Once a week	Continuous monitoring
Equipment modernization	Once worn out	Once outdated
Training	On the job, irregular	Off-the-job, professional, regular
Roles and positions	Narrow specialization	Wide-range of employees' qualifications
Production flow	Continuous, sequential	Discrete, parallel
Planning	Adjustive planning	Reacting to market needs, adaptive, forecasting

3 Paradigm change as the basis of concepts used in production management

3.1 Lean Manufacturing

old paradigm	new paradigm
production effectiveness achieved through mass production (specialization, economies of scale, taylorism)	production effectiveness achieved through lean manufacturing based on waste elimination

Lean Manufacturing is a conception which views use of resources for anything other than creating value for the customer as a waste. It allows the production of a greater amount of products while using fewer resources, hence "lean" ([44], p. 19). In contrast to the traditional approach, based on extensive use of production capacity, LM assumes that only what is needed is produced. This way system productivity, as well as product quality, and customer service improve. The main differences between the traditional and the lean approach are illustrated in Fig. 1.

Lean Manufacturing is based on five lean approach rules ([51], p. 16-26):

1) assessing the product's value from the client's needs perspective;
2) identifying value stream for each product;
3) ensuring smooth value flow in production process;
4) ensuring a pull production system;
5) striving for perfection through continuous improvement.

Their brief description as well as supportive methods and techniques are shown in Table 2.

One of the main principles of Lean Manufacturing is elimination of waste. It is possible thanks to the identification of activities ([51], p. 20):

- value adding,
- non-value adding, but necessary - indispensible to the process (muda of the Type One),
- waste - non-value adding and dispensable (muda of the Type Two).

In the literature 7 main types of waste (Jap. muda) are mentioned whose elimination results in the increase of enterprise productivity ([20], p. 75): overproduction, inventory, defects (repair/rejects), motion, processing, waiting, transportation.

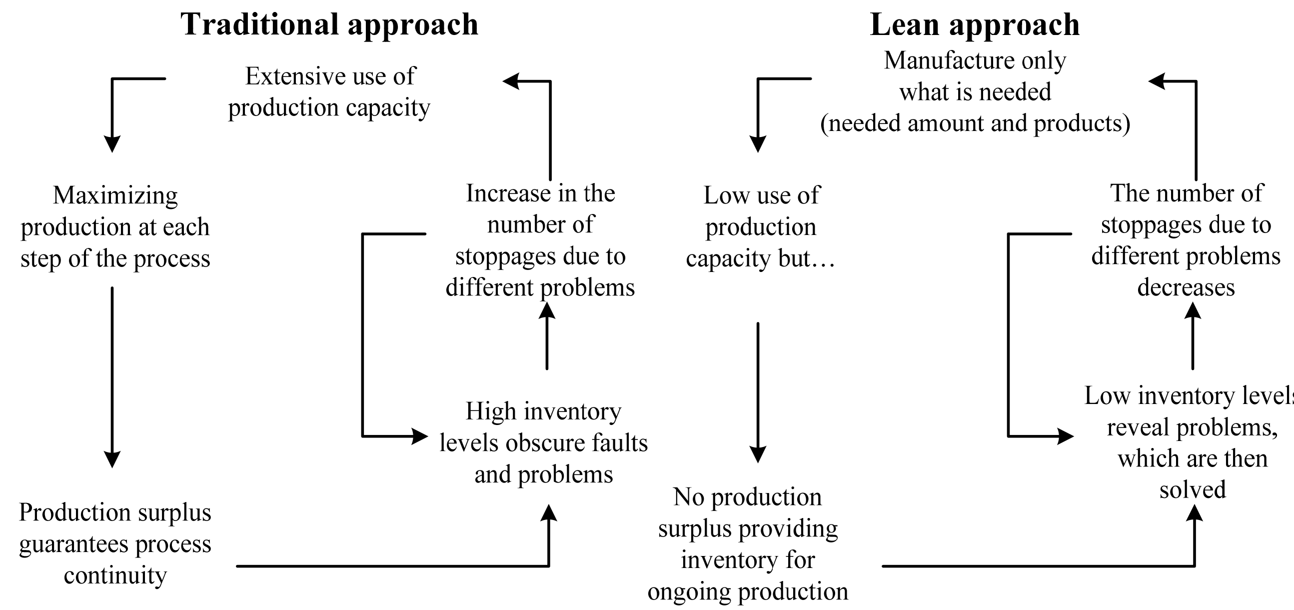

Figure 1. Traditional vs. lean approach to manufacturing (*source: self study*)

Table 2. Lean principles and techniques supporting them
(source: self study on the basis of ([25], pp. 67-7; [32], p. 108 and [52], p. 39)

Principle	Description	Techniques
1) Value	Can be only defined by the customer. Only has a meaning when it is being considered in terms of a specific product, which fulfils customer's needs at a specific price and at a specific time.	Voice of the customer, value engineering (VE), value analysis,
2) The value stream	The set of actions required to bring a product through the critical management processes of the business.	Value Stream Mapping (VSM)
3) Flow	Requires a fundamental change in thinking for everyone involved, as functions and departments that once served as the categories for organizing work must give way to specific products.	One Piece Flow, SMED, Heijunka, TPM- Total Productive Mainenace
4) Pull	No upstream function or department should produce a good or service until the customer downstream asks for it.	Supermarket, kanban, JIT delivery
5) Perfection	Processes in the company and its organization must be improved all the time. There is always something more to do to achieve perfection which is actually unreachable.	Muda elimination, Visual Control, 5S, Poka–Yoke, self-control, SPC, standardization, problem solving, PDCA cycle

3.2 Kaizen

old paradigm	new paradigm
enterprise competitiveness growth mainly through innovation	enterprise competitiveness growth mainly through continuous improvement of processes by small steps using expert employees'
taking decisions and knowledge are the director's domain – hierarchical management	knowledge, teamwork in solving problems, delegating authority

The Kaizen approach comes from Japan and reflects Oriental culture and way of thinking. Kaizen became widely popular in the West after the publication of Masaaki Imai's book "Kaizen: The Key to Japan's Competitve Success" in 1986.

Kaizen in Japanese means improvement (Jap. "kai" – change, "zen" – good). It denotes an approach focused on continuous improvement of the current conditions. It is done through small, gradual changes in processes, which accumulated over time make a substantive difference ([48], p. 2). Kaizen is underpinned by three main goals ([19], p. 128):

1) employees are the most important resource of the enterprise;
2) processes should evolve through gradual improvements rather than radical change;
3) improvements to be made are decided on the basis of a quantitative assessment of the results of particular processes.

The key principles of Kaizen are as follows ([20], pp. 2-7):

- maintaining and improving standards – maintaining relies on Kaizen activities, improving can be analyzed as either Kaizen or innovation,
- orientation towards processes – improving a process is fundamental to improving results,
- applying PDCA (plan, do, check, act) and SDCA cycles (standardize, do, check, act) – PDCA serves to establish new, better standards, SDCA is used to consolidate them and stabilize the level of results achieved,
- quality is number one priority – the main goals of the enterprise are related to quality,
- using data – referring to current data when solving a problem,
- the next process is the client – differentiation between the external client (in the market) and internal client (in the enterprise),
- engagement of all employees, management and rank-and-file employees alike.

Fig. 2 shows Kaizen and innovation concepts as well as how to achieve a radical improvement in a short time thanks to alternating between innovating and enhancing achieved standards using PDCA and SDCA cycles.

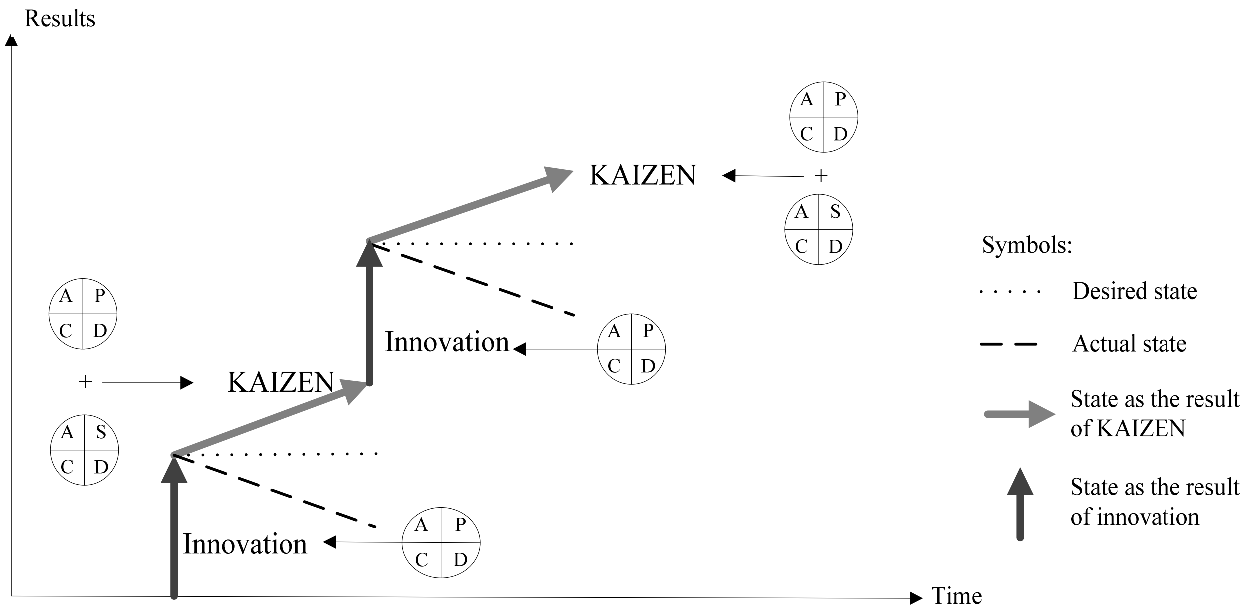

Figure 2. Innovations and Kaizen
(source: self study on the basis of [21], p. 29 and p. 64)

The basic idea of Kaizen is to introduce small, gradual changes. The opposite is sudden radical changes called innovations (including product, process, marketing, or organizational innovations). Daily practices are aimed at maintaining the achieved level. However, in reality the level decreases due to failing to observe standards.

Kaizen allows for improvement of the achieved level through small, gradual enhancements as in the SDCA cycle. This approach complements the one based on innovations and vice versa. Thanks to using Kaizen it is possible to enhance the processes usually up to a certain level. The next improvement requires introducing completely new solutions and that is when innovation is needed. Hence, both approaches, although based on different assumptions, are mutually complementary.

The Kaizen philosophy assumes that all employees are involved in the improvement process ([21], p. 12). Rank-and-file employees are seen as the main source of knowledge about how to carry out the work in the right way, the problem and the solutions to it. They have the greatest detailed knowledge about the problem – the higher up in the management the better is the employee's general knowledge of the situation and the less extensive their detailed knowledge. Hence the importance of increasing employee's authority, which is linked to the increase of responsibility and ability to take decisions in case of disturbances and clashes in the process.

Kaizen is supported by a range of methods and tools which make up the so called "Kaizen umbrella" ([21], p. 9). It includes such approaches as: Total Quality Control (TQC), suggestion system, Total Productive Maintenance (TPM), Kanban, Just-in-Time (JIT), as well as Zero Defects (poka-yoke). This shows the interdependence between Kaizen and other concepts used in production management, such as TQM (an extension of TQC), TPM and Lean Manufacturing (based on JIT).

3.3 Theory of Constraints

old paradigm	new paradigm
every resource not used is a waste; one should strive to maximize the use of all resources	only the resource which is the constraint cannot be left unused; use of resources which are not critical does not affect throughput of the production system

Theory of Constraints (TOC) is a concept created by E. Goldratt, which is based on the premise that the organization, like a chain, is as good as its weakest (not strongest) link. The fundamental notion in TOC is a constraint, defined as "anything which constrains the system in achieving better results regarding its goal” ([45], p. 385).

There are three main constraints categories ([45], pp. 388-389):

- physical constraints (bottlenecks) – resource or resources, which physically constrain the achievement of the goals of the system,
- policy – rules and measurements used to manage the enterprise,
- paradigms, basic assumptions, beliefs, values and principles underpinning the conception and development of the enterprises' policy.

The following principles of the Theory of Constraints can be formulated:

1) every organization has only a few constraints, elimination of which leads to radical improvement of results;
2) continuous system improvement is based on the POOGI (Process of Ongoing Improvement) - consisting of the following steps: what should be changed? what should be the result of the change? how should the change be made?
3) searching for improvements is a 5-step process:
   (a) identifying the constraint,
   (b) exploiting the constraint,
   (c) subordinating all other resources and activities to the constraint,
   (d) elevating the constraint,
   (e) returning to step (a) to complete the cycle of continuous development.

Now the Theory of Constraints is a complex approach to organization management, covering [8]:

1) tools for identifying constraints and solving problems, so called logical thinking tools;
2) a range of area-specific applications, often computer-aided, enabling effective constraints management in such areas as:
   (a) production management – DBR (Drum-Buffer -Rope) model,
   (b) distribution management,
   (c) project management – Critical Chain model,
   (d) sales management,
   (e) marketing;
3) human Resources management;
4) global and local measurements system, enabling financial decisions to be taken;
5) systematic method of creating the company's strategy and tactics, directed at a radical improvement of results.

TOC application for production management is called Drum-Buffer-Rope. Its consecutive steps use both tools (methods and techniques) specific to TOC and tools belonging to other concepts.

Identifying the constraint is the starting point, because the constraint affects the size of the production output. The decision about the way of constraint exploitation is aimed at increasing its production capacity. At this stage all methods of enabling the increase of production flow at the bottleneck are used, e.g.: eliminating all operations involving the bottleneck which can be done using different resources, minimizing the bottleneck changeover times (e.g. by using the SMED method), prioritizing the bottleneck regarding all maintenance support, making sure that no low quality materials get to the bottleneck and so on. The result of all these activities is “the drum”, i.e. the schedule maximizing the use of the bottleneck capacity.

The buffer and the rope allow for subordinating to the constraint almost every process in the enterprise related to production planning, materials purchase, or shipment of finished products. The buffer serves to guarantee the realization of the bottleneck work schedule even when there are disturbances resulting from random fluctuations in the process, e.g. delay in the completion of the previous operation. The rope in turn is a mechanism for identifying the moment of moving the material to the first operation of the production process so that the right amount of intermediate products reaches the bottleneck in time. The concept of Drum-Buffer-Rope method is shown in Fig. 3.

Elevating the constraint should be considered only after exploiting all the potential of the constraint. When there are still possibilities of increasing sales (market is not a constraint) elevating constraint can be done through increasing its throughput, e.g. by buying a new machine. Returning to step one completes a cycle of continuous development – the same procedure is repeated for a new constraint.

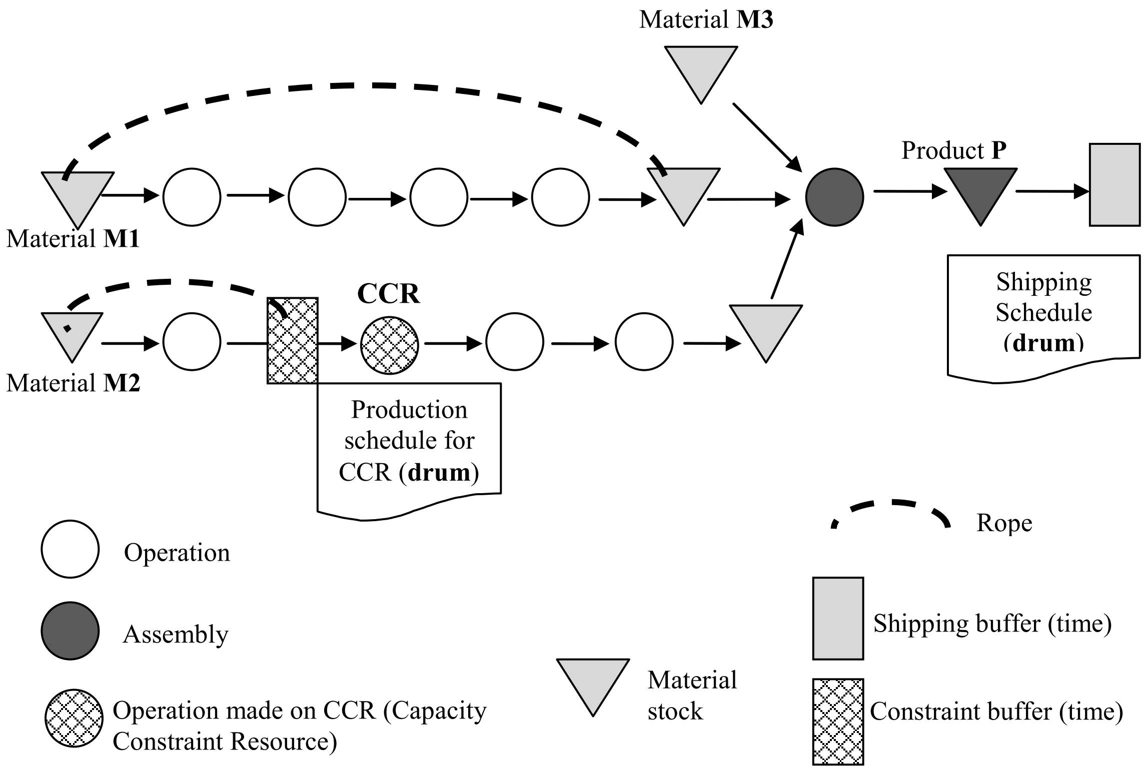

Figure 3. Drum-Buffer-Rope
(source: self study)

3.4 TQM

old paradigm	new paradigm
product-orientated	client-orientated, identifying internal and external customers
the responsibility for quality is with the quality control department	the responsibility for quality is with every employee

TQM (Total Quality Management) comes directly from the Japanese concepts of TQC (Total Quality Control) and CWQC (Company Wide Quality Control). They were adapted for the USA and then spread in the West. One of the main authors of TQM is William Edwards Deming, who created 14 principles of quality management.

TQM is an approach to enterprise management which views enterprise operations as a process in need of improvements in order to satisfy client's needs. It is possible through engaging all employees in matters of quality. In other words, TQM is an approach to the management of the enterprise as a whole in order to achieve its excellence [1].

TQM is based on 5 principles ([9], p. 30):

1) focusing on clients – there are external clients (the recipients of the final product) and internal clients (the organization's employees who receive the intermediate product);
2) continuous improvement (Kaizen) – continuous improvement of the processes to satisfy clients;
3) focusing on facts – decisions should be taken based on facts, which is possible thanks to the use of a constant measurement, observation, and data-collection system;
4) common involvement – the requirement of all the employees being involved in quality matters;
5) management involvement – informs and shows the employees that quality matters are of utmost importance.

Some mention as many as 8 principles relating to TQM, introduced by ISO 9000:2000 as principles of quality management. These principles are as follows ([41], p. 17):

1) client orientation;
2) leadership;
3) employees' involvement;
4) process approach;

5) system approach to management;
6) continuous improvement;
7) factual approach to decision making;
8) mutually beneficial supplier relationships.

Principles (4), (5) and (8) are those added to the traditionally recognized ones. These principles negate the so called traditional approach to quality, realized first as quality inspection, then quality control and finally quality assurance. The old and new attitudes to quality are contrasted in Table 3.

TQM is a concept relevant to both production management and quality management. It is supported by a range of methods and tools applicable to both these areas ([6], pp. 116-120):

- traditional TQM tools: 7 old quality tools, 7 new quality tools, 7 supporting quality tools,
- methods of quality planning: DOE (Design of Experiments), FMEA (Failure Mode and Effects Analysis), Taguchi method and QFD (Quality Function Deployment),
- methods of quality improvement: FMEA (Failure Mode and Effects), SPC (Statistical Process Control).

3.5 TPM

old paradigm	new paradigm
responsibility for the technical condition of machines is with the maintenance department	responsibility for the technical condition of machines is with everyone

TPM (Total Productive Maintenance) is a strategy of maximization of total effectiveness of machines and equipment. It prescribes continuous improvement of equipment with active involvement of employees responsible for the workplace and maintenance ([11], p. 158). In contrast to the traditional approach, in which it is the maintenance department who are responsible for the condition of the machines, TPM proposes that it is the machine operator who knows best how the machine works and how to keep it in the best condition.

The five pillars of TPM are ([46], p.11-12):

1) planned maintenance system, introducing three types of maintenance: preventive, modernizing and diagnostic;
2) autonomous maintenance done by the machine operators;
3) improvement activities aiming at improving the efficiency of machines;
4) preventing repairs through a system of designing and selecting machines;
5) training system for employees involved in TPM.

Progress in TPM is measured mainly by calculating OEE (Overall Equipment Effectiveness), which is a measurement linking machines availability, their performance and the quality of the manufacturing process. It is calculated by multiplying these three. OEE is improved mainly by eliminating Six Big Losses, presented in Table 4.

Table 3. The old and new approach to quality
(source: [1], p. 25)

Factors	Old approach	New approach – TQM
Orientation	Towards the product	Towards the customer
Decisions	Short-term Based on intuition and beliefs	Long-term Based on facts and data
Focus on	Identifying mistakes	Preventing mistakes
Responsibility for quality	Quality control department	All employees
Problem solving	Managers individually	All employees as a team
The role of the manager	Planning, controlling, executing	Delegating authority, coaching

Table 4. Six Big Losses in TPM
(source: self study on the basis of [50], p. 5 and [52])

Six big losses	Category	Examples	Calculating OEE
Breakdowns	Down time loss	Unplanned maintenance Machine breakdowns	Availability
Setups and adjustments	Down time loss	Adjustments Setup/Changeover Material shortages	
Awaiting work and small stops	Speed loss	Obstructed component flow Delivery blocked Control	Actual efficiency
Reduced speed	Speed loss	Rough Running Equipment Wear Operator Inefficiency	
Startup rejects	Quality loss	Repairing defects Rework In-process damage Incorrect assembly	Product quality metric
Production rejects	Quality loss		

In order to support the implementation of TPM the following tools are used ([47], pp. 111-132):

- graphs showing machines performance metrics, including OEE metric, radar graphs,
- tools for identifying and solving problems: Pareto-Lorenz's diagram, Ishikawa diagram etc.,
- statistical tools, including histograms, SPC control charts,
- 5S practices,
- waste elimination,
- PDCA cycle and standardization of best practices
- visual control,
- quick changeovers: SMED,
- FMEA templates – Failure Mode and Effects Analysis.

TPM is the leading approach used in production management in enterprises in continuous operation such as energy and metallurgical plants, as well as food business operators, pharmaceutical and chemical companies, and paper manufacturers, because their productivity depends first of all on the efficiency of their machines, equipment and complex manufacturing installations.

3.6 Six Sigma

old paradigm	new paradigm
quality assurance programs are focused on detecting and correcting defects	there are methods of carrying out processes which prevent defects from coming about

It is very difficult to capture the essence of Six Sigma so that it can be characterized by means of one paradigm, because it is actually an extension of TQM. There are many definitions of Six Sigma, among them the following one: "Six Sigma is a complex and flexible system of achieving, maintaining and increasing success in business. It is characterized by understanding customer needs and using facts, data and statistical analysis results. It is aimed at managing, streamlining and improving solutions related to processes of the organization." ([24], p.193).

The essence of Six Sigma is quality management based on the measurement of results ([16], p. 193). Six Sigma is focused on defining the metrics of customer satisfaction at every stage of the process. These metrics are the reference in streamlining the process. The synthetic metric of the process level is the so-called sigma value, which is related to the DPMO metric (defects per million opportunities). The process is at level 4σ if the number of defects per million opportunities is not greater than 6210 (see Table 4).

The basis for improving processes in Six Sigma is the understanding of variation and the ability to identify general and specific causes of variation. There are three main sources of variation, which are interdependent ([17], p.142):

- incorrect margin of error assumed at the stage of product and process planning (setting tolerance limits),
- variation related to intermediate products and materials provided by external suppliers,
- limited ability of own production processes to satisfy customer demands regarding critical quality parameters.

An integral element of Six Sigma is carrying out detailed measurements (by SPC, Statistical Process Control, among other methods), which allow general and specific causes of variations to be identified, and improvement projects aimed at the reduction and/or elimination of variations to be carried out.

The basis of all Six Sigma projects is data allowing changes in customer needs and demands as well as all deviations from target values to be detected (see Fig. 4).

A commonly used and effective method of carrying out Six Sigma projects is the improvement process based on DMAIC cycle. The cycle is supported by different tools used in specific phases (see Table 6).

Recently, the Six Sigma concept has been associated with Lean Management philosophy. They have come together as the Lean Six Sigma approach focused on creating a "lean" process, free from variation, as well as customer-oriented products. Six Sigma consists of the following elements ([31], p. 7):

- Product development – covering product and process planning,
- Lean Management – focused on waste reduction and process cost cuts,
- TQM – process management and optimization,
- ISO – aimed at standardization and optimization of processes.

Table 5. The sigma quality level versus DPMO number
(source: self study on the basis of [37], p. 28)

Sigma quality level	1	2	3	4	5	6
The maximum number of DPMO (defects per million opportunities)	697 700	308 537	66 807	6 210	233	3,4
The percentage of quality criteria-compatible products in the overall number of manufactured products	30,9	69,2	93,3	99,4	99,98	99,9997

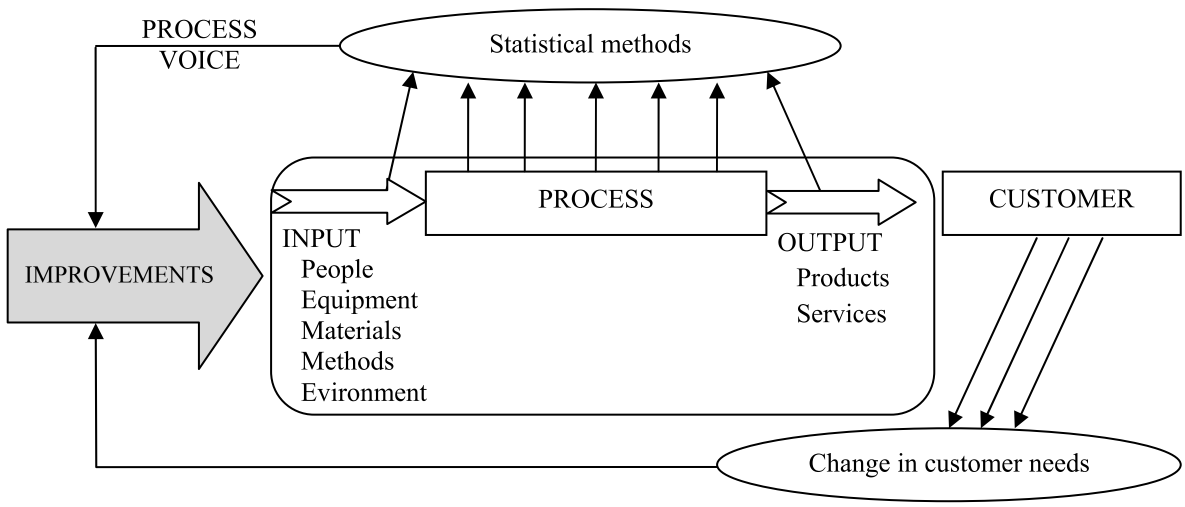

Figure 4. Six Sigma improvements process model
(source: self study)

Table 6. DMAIC cycle and its tools
(source: self study on the basis of [31])

Cycle phase	Description	Tools used
D – define	Defining projects, problems, measurements, reference levels, aspects critical to quality.	Customer Voice Chart, Kano Model, CTQ Matrix/CTB Matrix, Cause-and-Effects (Ishikawa) Diagram, QFD, Pareto Chart.
M – measure	Measuring the current state of the key process, establishing and verifying the process measurement system.	Measurement Matrix, Data Source Analysis, Gage R&R, Graphs and Charts, Process Capability Calculations, Data Collection Forms, Measurement System Analysis, Statistic Plot and Parameters, Histogram, Control Chart, Scatter Plot.
A – analyze	Statistical data analysis allowing the most important factors affecting the defined critical aspect to be identified.	Cause-and-Effects (Ishikawa) Diagram, Process Mapping, Value-Stream Map, Spaghetti Diagram, Value Analysis, Time Analysis, DoE – Design of Experiments, Histogram, Correlation, ANOVA.
I – improve	Improvement in order to reduce the level of defects and deviations.	TOC, 5S, SMED, Pull System, Poka Yoke, TPM, Creativity Techniques, Tools for Selecting Solutions, Implementations Planning.
C – control	Controlling aimed at maintaining the achieved quality level.	Process Documentation, Monitoring/Control Charts (SPC), Reaction Plan, Checklist for the Control Phase, Project Closure

3.7 Process approach and Business Process Re-engineering

old paradigm	new paradigm
division of labor according to functions – optimization of results within functions and specializations	local optimization (within functions) does not lead to whole system optimization, because key results are related to interdependence among different functions
functional specialization leads to efficiency and quality growth	the process approach integrates product and process planning, manufacturing and after-purchase service

Business Process Re-engineering (BPR) was created as a response to the changes in industry in the 90s: fierce competition, growing customer expectations, and technology development, especially in the IT field. M. Hammer and J. Champy, the authors of BPR, say this methodology means “The fundamental rethinking and radical redesign of business processes to bring about dramatic improvements in performance.” ([15], p. 3).

BPR assumes a transformation of functional, hierarchical structures into horizontal process structures. The changes happening within the organization are revolutionary and radical in character. This has been the reason why many attempts at BPR-based organizational transformation have actually failed. Still, BPR foregrounded the importance of the process, which led to the conception of the process approach.

The process approach, known also as horizontal or systemic, means the organization is focused on the processes within it. This approach is the opposite of the traditional approach to organization management, called vertical or functional. Rummler G. and Brache A. described a phenomenon, characteristic of the functional management approach, known as the silos effect ([43], p. 32-33). Silos – tall buildings with thick walls and no windows - appear around functional departments and make it difficult - or at lower organizational levels even impossible - to solve problems shared by more than one department.

As Rummler G. and Brache A. write ([4]3, p. 32-33): “The silo effect means that managers of a higher rank are forced to deal with problems of lower ranks and are thus driven away from tackling more serious issues connected to customers and competitors. Rank and file employees who could deal with these problems themselves do not take full responsibility for results and see their own role as merely carrying our instruction and providing information. “(…) However, optimization at the department level only leads to worsening (suboptimization) of the results of the organization as a whole.” The silo effect does not appear in organizations managed in accordance with the process approach.

Efforts made to improve quality and customer satisfaction led to a change in the approach from vertical to horizontal. It was recognized that fundamental problems appear on the border between functional departments: procurement, production, sales, quality control, and maintenance departments. This was pointed out by Rummler [43, p. 35]: “(…) the greatest opportunities to increase productivity often lie at the border between different departments – at the points where the buck (e.g. production specifications) is passed from one department to another. Problems of this kind can only be solved when process-oriented thinking is applied”.

Changes which resulted in production process-oriented thinking started at Toyota plants: the famous one-piece flow. The concept of Lean Manufacturing is in its essence a methodology of process-oriented management. The characteristics of process-oriented management can be summarized as follows ([7], p. 285-286):

- focus on process results and process management,
- restructuring (improvement) of processes regarding QCDF (quality, costs, deadlines, flexibility),
- focus on value stream, identifying operations adding value (for the customer), reduction of non-value adding but indispensible operations, elimination of waste,
- the owner of the process, processes simplified, but the tasks of individual employees more complex, enforcing human resources development,
- regulation of process operation through the introduction of the customer (external/internal) – supplier relation,
- horizontal communication, reduction of hierarchical levels, one coordinator (process owner).

Changes to process-oriented thinking should take place in the following areas ([49], p. 225):

- manufacturing processes – combining functions such as: research, development, distribution into one process,
- product development – cooperation of experts from different departments of the enterprise,
- internal and external relations – including suppliers and customers in the product development process,
- creating teams – creating interdepartmental teams to work on streamlining processes.

There is a range of methods and techniques supporting the above activities in restructuring production processes:

- Tools for process mapping, value-stream mapping “from door to door” in the factory,
- Kanban pull system,
- SPC statistical process control,
- Poka-yoka - mistake proofing,
- Deming cycle (PDCA and SDCA).

The process approach is used not only for restructuring production processes, but for changing all business processes and for all organizations, not only production enterprises.

3.8 Other concepts applied in production management

Some other concepts should be mentioned here which are less often used due to their limited applicability, or the generality of their character and lack of developed methods and specific techniques facilitating their implementation.

3.8.1 Agile manufacturing (AM)

Agile manufacturing is characterized as a strategy directed at the development of organization capacities so that the organization can function better ([42], p. 8). It is described as the next stage of development in production management methodology after LM. The biggest difference between these concepts is that while LM assumes that changes can take some years to happen and cooperation with suppliers requires time, AM authors say that changes result from strong competition on the market and should be made as soon as the need arises ([42], p. 5).

AM is based on two key principles:

- innovative alliances with suppliers, customers and other producers in order to add value for the customer,
- investing in flexible and modern production technologies.

The aim of agile manufacturing is an almost immediate delivery of small batches satisfying customer needs [14]. Hence it is applied in mass, repetitive, and serial production.

AM can use methods and techniques of other production management concepts, such as LM or TOC. However, it has its own tools as well ([42], p. 10-11):

- transactional analysis: based on research into the organization's functioning; allows gaps to be detected in the development of the enterprise and points out the direction of development,
- activity/cost chain: allows activities carried out in the enterprise to be linked with specific costs; knowing the cost allows the improvements introduced to be assessed,
- organization maps: serve to picture cooperation with suppliers; can be particularly useful when planning new products,
- key characteristics: created for high profile products; serve to specify customer demands and cater for them at the construction and production stage,
- contact chains: link key characteristics with product structure.

Agile manufacturing is very closely linked to CE (Concurrent Engineering) or SE (Simultaneous Engineering), which are methods of simultaneous development of the concept of the product, its construction, manufacturing processes, starting and adjusting production. It reduces the length of the product manufacturing process and minimizes costs. Organization-wise it means creating interdisciplinary expert teams who are responsible for quickly introducing the product to the market. These techniques cover ([10], p. 184):

- creating an innovative product concept and construction planning,
- quick prototyping and testing prototypes,
- production processes planning,
- quick manufacturing of special tools and equipment,
- quick single product manufacturing.

3.8.2 Mass customization (MC)

Mass customization is a new management concept based on the integration of mass production with production fulfilling an individual customer's expectations. It entails translating customer needs into a finished product, which is produced and delivered in a short time with production efficiency being high ([2], p. 7). It requires craft production to be combined with modern manufacturing technologies ([5], p. 2). This is achieved thanks to modular product construction and using a flexible production system. Table 7 contrasts MC with mass production.

The methods and techniques of this approach include [2] and ([3], pp. 228-229):

- voice of the customer,
- product portfolios,
- SMED – quick changeovers,
- value analysis,
- concurrent manufacturing.

It should be noted that the methods used within this approach are not fully formalized and characterized. This is a result of both the short history of AM application and attempts at adjusting known methods and techniques to use within it.

3.8.3 Management by projects

The concepts used in production management which were outlined above are relevant mainly for mass and serial production, that is production which is repetitive in a more or less regular way. There are however many enterprises which offer unique products, e.g. construction companies, shipyards, enterprises providing complex production installations, as well as IT companies providing dedicated IT systems or adjusting standard systems for the customer. Such enterprises should be managed through projects, because they simultaneously carry out a range of projects, which appear unrelated but use the same resources.

A project is characterized by carrying out a sequence of activities in order to achieve unique results in a specific timeframe ([33], p. 20-21). Projects have specific deadlines and are usually unique. "Project management" could be defined as ([23], p. 18-19): planning (what should be done), organizing (how this should be done), implementation (realization of planned activities), and control (maintaining the direction which was set out). “Management by projects” covers managing multiple projects at the same time and includes ([7], p. 333): defining values, specifying priorities, solving conflicts between projects, as well as defining organizational structure and the rules of its functioning.

The concepts of project management and management by projects evolve in time. The key change tendencies are illustrated in Table 8.

The concept of management by projects also constantly evolves. In the literature one can find characteristics of concepts linking project management with many modern management methods. In “Lean Projects Leadership” [29] the authors suggest combining the principles popularized by PMI (Project Management Insti-Institute) in PMBOK^{TM} Guide with LM, TOC (Critical Chain application), and Six Sigma.

Table 7. Mass production versus mass customization
(source: self study on the basis of [40], pp. 47)

Aspects	Mass production	Mass customization
Focus	Efficiency through stability and production control	Customization through flexibility and capacity for quick reaction
Aim	Development, production, marketing, and shipping done so that costs and prices are kept low	Development, production, marketing, and shipping done so that variety satisfying customer needs is maintained
Main principles	- Stable demand - Vast, homogenous market - Low costs, satisfactory quality, standardization of products and services - Long product development cycles - Long product cycles	- Fragmented demand - Heterogeneous market - Low costs, high quality, products and services adjusted to customer needs - Short product development cycles - Short product cycles

Table 8. Changes in project management in the direction of management by projects
(source: self study on the basis of [7], p. 318-319 and [29], p. 1.2-1)

Aspects	From	To
Project size	Small	Big, complex
Project length	Short (a few days)	Long (a few years)
Production type	One-off production clearly separated from repetitive, serial production	Blurring of differences, a growth in the number of projects realized by the enterprise
Organizational structure	Functional, matrix	Horizontal, task-based Hierarchical structure destabilized
Management type	Classic	Management by projects
Project definition	Project as the source of over employment and fluctuation of managers	Multiple projects = complexity of management + necessity for flexibility and reactiveness + autonomy
Project manager role	Little knowledge of project manager’s function	The role of project manager is appreciated
Methods and techniques	Gantt and PERT graphs, CPM method, computer programs for project management (e.g. MSProject, P2Ware Planner)	Using modern techniques with emphasis on human factors. Additionally, modern tools such as Intranet and Extranet are used
Knowledge accumulation	Knowledge accumulates in the project manager’s head Unique experiences	The necessity for capitalizing knowledge and experience through the use of IT networks and databases
Workplace	Chaotic	Focused on projects and their flow

3.8.4 Production knowledge management

The classic strand of management was underpinned by the assumption that an enterprise can be managed as an object, a collection of human and material resources. Knowledge management is focused on the immaterial resource of knowledge and is a response to changing business conditions such as virtualization of business activities and increasing importance of information processes.

Knowledge management ([22], p. 20) is understood as a process of acquiring, developing, codifying, distributing and using information, knowledge, and experience, allowing for future growth of the enterprise drawing
on its technological and human resources. It is widely applied in production enterprises thanks to the potential of project, process, and organizational innovation that it offers.

For the sake of this paper the focus is on a specific type of knowledge identified by production enterprises – production knowledge. This knowledge is used mainly at the operational and tactical level, and to a lesser extent at the strategic level. Production knowledge is knowledge about products, production systems and processes, as well as ways of manufacturing. These elements of production knowledge are stored either in a structured form as, among other things, plans, instructions, procedures, and standards, or in an unstructured form. Production knowledge includes knowledge about the best practices in production preparation and planning, in particular in the areas of planning, organizing, leading, and controlling production. The production management process, including production knowledge resources, can be presented as in Figure 5.

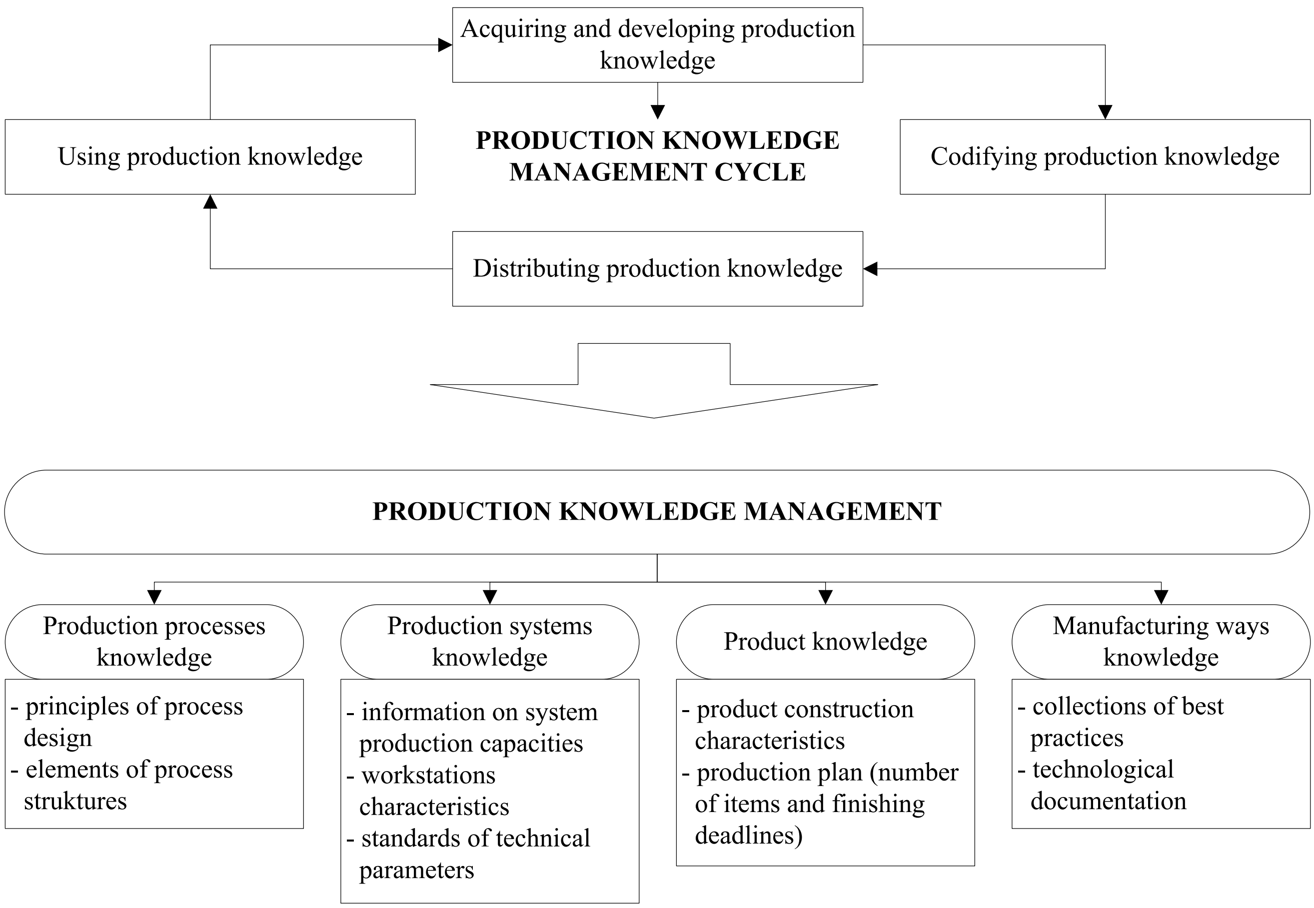

Figure 5. Production knowledge management cycle
(source: self study on the basis of [22], p. 20 and [39], p. 372)

The importance of knowledge management is recognized by the managers of production enterprises. This is linked to the appreciation of such characteristics of knowledge as the fact that it ages, quickly becomes outdated and is at risk of being losing. At the same time knowledge is a resource which increases with time. In production organizations two fundamental types of knowledge are identified:

- explicit knowledge – clearly defined, systematized, coherent, objective, rational and presented formally,
- tacit knowledge – intuitive, subjective, experiential, not formalized ([38], p. 45-46).

Tacit knowledge is difficult to manage, because it is the individual knowledge of each employee. It is possible to transform knowledge from tacit to explicit ([13], p. 79-80), which facilitates management processes.

Production knowledge management is a concept which supports other concepts of production management and is based on them. The experience acquired while streamlining production processes and the documents created when applying particular methods enrich production knowledge. Table 9 shows tools used at particular stages of knowledge management.

4 Interactions between modern management concepts

Many authors [34, 36, 4 and 11] point out the dynamic development of management tools, their interchangeability, complementarity, and the need for systematization.

Table 9. Tools for production knowledge management
(source: self study)

Stages of production knowledge management	Tools for production knowledge management
Acquiring and developing production knowledge	- Tools for examining process sequence: Process Chart, Material Flow Chart, Process Flow Chart, Team Activities Chart, Two-Handed Process Chart, Working Day Photography Sheet, Snaphot Observations Sheet, Standardized Work Sheet, Standardized Work Combination Table, Production Capacity Chart, - Tools for examining flow: Spaghetti Diagram, Value-Stream Map, - Tools for process analysis: Cause-and-Effects (Ishikawa) Diagram, Pareto Chart
Codifying production knowledge	- Standardized Work Documentation (Standardized Work Sheet, Standardized Work Combination Table, Production Capacity Chart, Operator Balance Chart, Failure Mode and Effects Analysis), - Value-Stream Map, - Instructions (workstation, cleaning, Total Productive Maintenance) - Check Lists - Operation sheets - Construction documentation
Distributing production knowledge	- Internal training based on instructions - Work based on Standardized Work Sheets - Process visualization - Team work
Using production knowledge	- Learning by doing - Solving problems based on production documentation

This problem is noted also by J. Lichtarski ([30], p. 167), who talks about “the jungle of management theories” and the need for systematizing it. He introduces the notion of “orientation”, defining it as “[…] theoretical-methodological direction of thinking and its results in management science, as well as consulting activities and practical applications which accompany it and are based on a particular idea expressed in values, leading paradigm, principles of this/these direction(s). […] Implementation of these orientations is done by applying methods, tools, and concepts specific for them, and is gradual and evolutionary in character.” Lichtarski distinguishes the following modern orientations in management: market orientation, quality orientation, results orientation, human orientation, strategic orientation, process orientation, change orientation, and knowledge orientation. The values, principles and guidelines specific for each orientation can be introduced to the enterprise through different concepts, methods and tools, which is illustrated in Table 10.

Most often these philosophies are implemented independently, or in a way only incidentally linked, which is pointed out by, among others, S. Nowosielski ([36], p. 10). The interaction between them as well as their shared methods and techniques are not taken advantage of as they should be. These concepts are so closely related that it is sometimes hard to tell whether a given solution is implemented as part of TQM or LM. Recently one can hear more and more often about Lean Six Sigma [31], a system combining LM and Six Sigma, or even about TLS – a combination of TOC, LM and Six Sigma. Many methods and techniques are used in different approaches. For example, 5S practices and continuous improvement philosophy are present in all systems, SMED is considered a tool of LM and TPM, and statistical process control is seen as an element of TQM, Six Sigma, and Lean Manufacturing as well. Table 11 illustrates the chosen methods, approaches and tools present in different concepts, and their interdependence and complementarity.

Approaching existing management models separately from each other results in creating separate organizational structures, documentation systems, training programs etc. The lack of coordination makes organization management system very complicated and means that the potential for synergy, coming from the fact that a lot of methods and specific techniques are common for different models, is squandered. Additionally, uncoordinated implementation of different concepts often fails if implementing more advanced tools is not preceded by using less advanced methods.

Table 10. Relations between orientations in enterprise activity and management concepts
(source: self study)

Orientation	Management concepts						
	LM	TOC	kaizen	TQM	Six Sigma	TPM	BPR
market	√	√		√	√		√
quality	√		√	√	√		
results	√	√		√	√	√	√
human	√		√	√	√	√	
strategic	√	√		√	√	√	√
process	√	√		√	√		√
change	√	√	√	√	√	√	√
knowledge	√		√	√		√	

Table 11. Chosen methods and tools used in key methodologies of production management
(source: self study)

Methods and tools	Management concept						
	LM	Kaizen	TOC	TQM	TPM	Six Sigma	BPR
Process approach			●	●		●●	●
Continuous improvement	◑	●	●	●	●	●	●
Value engineering	●	◑				●	◑
Process mapping	●		◑	●		●	●
One piece flow	●		◑				
Waste elimination	●	●		●	●		●
Pull system	●		●				
Supplier collaboration	●		●	◑		●	◑
5S	●	●	●	●	●	●	●
Poka-Yoke	●			●		●	●
Visual control	●	●		●	◑		
SPC	◑	●		●		●	●
Standardization	●	●		●	●	●	●
PDCA/SDCA cycle	◑	●		●	◑	●	●
SMED	●		●		◑		
Heijunka	●						
Kanban	●	◑					●
FMEA	●			●	●	●	

The symbols mean that the given concept uses methods/techniques:
◑ partly, ● fully

5 Conclusion

In this paper the key modern concepts used in production management were characterized along with the paradigms which accompanied their development. It is worth noting that concepts and methods used in management have a life cycle of their own, similarly to a product on the market, from its inception to growing popularity to maturity and finally decline when the managers turn to new tools.

New management concepts are usually accompanied by groundbreaking publications or articles characterizing the principles of new concepts, which was highlighted in the paper. At the development stage the concept is gradually acquiring a range of methods and techniques, which allows its leading principles to be implemented. That has also been pointed out in this paper. Consulting companies offer trainings and implementation support services related to the new methods. These new methods also make their way into university curricula.

At the maturity stage using a given concept becomes a must for the successful enterprises. Companies share their experience and achievements, the scientists do research into the concept, its applications and methods related to it and numerous academic and popular publications devoted to it appear. Z. Martyniak ([32], p. 341) calls this phase a "great diffusion". At the decline stage the popularity of the concept decreases and the attention shifts onto new ideas, which often take over some of the methods and techniques used in older management methodologies.

Regarding the lifecycles of particular concepts it could be argued that TQM is currently in the maturity phase, while Six Sigma is at the stage of dynamic development, and that Six Sigma uses to a great extent tools developed within the TQM framework. The situation is similar with Lean Manufacturing and Constraints Theory, which uses LM techniques. That is why Agile Manufacturing was not classified as a key concept used in production management – it appears to be still in the initial phase. It has not yet developed its own tools (methods and techniques) and it is difficult to foresee whether it will become a more permanent element of management practice.

A new paradigm accompanying the new concept is fully evident only at the stage of concept maturity, when the synthesis at a higher level of generality is possible. It is often very difficult to formulate the paradigm so that the essence of the new concept and the change in the way of thinking it represents is captured.

Changes in the production management paradigms play a key role in the development of modern management frameworks. They result from the changes in the external environment. New production management paradigms are compatible with the present economic conditions, in which the key success factors are thought to be customer satisfaction, flexibility in reacting to the change in customer needs and market situation, high product and customer service quality, as well as productivity of the owned resources.

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